

trate into the interior, and electric currents circulating in the sphere in parallel planes will cause a magnetic force opposed to that due to the moving charges. If the conductivity be perfect, these currents will persist, and the interior of the sphere will be permanently free from either electric or magnetic force; but, with finite conductivity, the currents will die away, and the magnetic force will finally attain a definite value inside the sphere, although the electric force vanishes. In each of these cases a solution is easily found; but while the currents are dying away the magnetic energy gradually changes, and the calculation of the energy at any given time might be difficult. I therefore confine myself to the two limiting cases. The case of the final stage when there is finite conductivity I had solved when Dr. Heaviside suggested to me that I should include the case of infinite conductivity in my investigation. The present communication is the outcome of that suggestion.

The sphere is of radius a , and carries a charge Q at a speed u , which is very small compared with v , the velocity of light; the strength of the field is F , and the specific inductive capacity is c . I employ Dr. Heaviside's units in order that my results may be comparable with his. The origin is at the centre of the sphere, and the axes of x and y are respectively parallel to the direction of motion and to the direction of the uniform electric field.

When u/v is very small, the electric force E , due to the moving sphere, is the same as if the sphere were at rest, and is therefore derivable from a potential function. Since there is no electric force inside the sphere, the induced distribution on the sphere produces the potential Fy at internal points, and hence produces the potential Fa^3y/r^3 at external points. Thus at internal points the components of E are

$$E_1 = 0, \quad E_2 = -F, \quad E_3 = 0,$$

while at external points they are

$$E_1 = \frac{Qx}{4\pi cr^3},$$

$$E_2 = \frac{Qy}{4\pi cr^3} + Fa^3 \left(\frac{3y^2}{r^5} - \frac{1}{r^3} \right),$$

$$E_3 = \frac{Qz}{4\pi cr^3} + Fa^3 \frac{3yz}{r^5}.$$

Finite Conductivity, Final Stage.—In this case the magnetic force is entirely due to the motion of the charge on the sphere, and we have

$$H_1 = 0, \quad H_2 = -ucE_3, \quad H_3 = ucE_2,$$

and thus $H^2 = u^2c^2(E_2^2 + E_3^2)$.

If, now, we write

$$x = r \cos \theta, \quad y = r \cos \phi \sin \theta, \quad z = r \sin \phi \sin \theta,$$

we find that for internal points $H^2 = u^2c^2F^2$, and that for external points

$$H^2 = u^2c^2 \left[\frac{Q^2 \sin^2 \theta}{16\pi^2 c^2 r^4} + \frac{QFa^3}{2\pi cr^5} \cos \phi \sin \theta (3 \sin^2 \theta - 1) + \frac{F^2 a^6}{r^6} \left(1 - 6 \cos^2 \phi \sin^2 \theta + 9 \cos^2 \phi \sin^4 \theta \right) \right].$$

The magnetic energy is $\frac{1}{2}\mu H^2$ per unit volume, and thus the total magnetic energy is

$$T = \frac{1}{2}\mu u^2 c^2 F^2 \cdot \frac{4}{3}\pi a^3 + \frac{1}{2}\mu \int \int \int H^2 r^2 \sin \theta \, dr \, d\theta \, d\phi,$$

where r ranges from a to infinity, ϕ from 0 to 2π , and θ from 0 to π . On effecting the integration, we find

$$T = \frac{1}{2}\mu u^2 [\mu Q^2/6\pi a + 16\pi\mu^2 F^2 a^3/5] = \frac{1}{2}mu^2,$$

where m is the magnetic inertia.

For motion parallel to F instead of right angles to it, Dr. Heaviside finds (NATURE, April 19)

$$T = \frac{1}{2}\mu^2 [\mu Q^2/6\pi a + 8\pi\mu^2 F^2 a^3/5].$$

When the quantities are measured in ordinary units the results become

$$T = \frac{1}{2}u^2 [2\mu Q^2/3a + 4\mu^2 F^2 a^3/5] \quad (\text{Searle})$$

and

$$T = \frac{1}{2}u^2 [2\mu Q^2/3a + 2\mu^2 F^2 a^3/5], \quad (\text{Heaviside})$$

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where, if we use C.G.S. electromagnetic units, we have $\mu = 1$ and $c = (3 \times 10^{10})^{-2}$.

Infinite Conductivity.—In this case a system of currents flows round the sphere, on its surface, in planes normal to the axis of z , the distribution being such as to give rise to a magnetic potential $-ucFz$ at internal points. The magnetic force due to these conduction currents then neutralises, at internal points, the magnetic force $-ucF$ due to the moving charges. The external magnetic force due to the conduction currents will satisfy Laplace's equation for very slow speeds, and must, therefore, be expressible in zonal harmonics, while, for all speeds, the magnetic force normal to the sphere must be continuous. If $z/r = \cos \psi$, the normal force at points just inside the sphere is $ucF \cos \psi$. The conditions are satisfied by the external potential

$$\Omega = ucFa^3 \cos \psi/2r^2 = ucFa^3 z/2r^3,$$

for this is a zonal harmonic, and gives rise to the normal force $ucF \cos \psi$ at the surface.

Thus, at external points,

$$H_1 = -d\Omega/dx, \quad H_2 = -d\Omega/dy - ucE_3, \quad H_3 = -d\Omega/dz + ucE_2,$$

where E_1, E_2, E_3 have the values already given. We thus find

$$H_1 = \frac{3ucFa^3xz}{2r^5},$$

$$H_2 = -\frac{ucQz}{4\pi cr^3} - \frac{3ucFa^3yz}{2r^5},$$

$$H_3 = \frac{ucQy}{4\pi cr^3} + ucFa^3 \left[\frac{6y^2 + 3z^2}{2r^5} - \frac{3}{2r^3} \right].$$

It will be found that $xH_1 + yH_2 + zH_3 = 0$ for all values of r , and thus the magnetic force is tangential to the sphere, a condition pointed out to me by Dr. Heaviside.

Hence we find

$$H^2 = u^2c^2 \left[\frac{Q^2 \sin^2 \theta}{16\pi^2 c^2 r^4} + \frac{3QFa^3}{4\pi cr^5} \cos \phi \sin \theta (2 \sin^2 \theta - 1) + \frac{F^2 a^6}{4r^6} \left\{ 36 \sin^4 \theta \cos^2 \phi - 9 \sin^2 \theta (4 \cos^2 \phi + \sin^2 \phi) + 9 \right\} \right].$$

Remembering that $H = 0$ at points inside the sphere, we find, on integration through the external space, that the magnetic energy is

$$T = \frac{1}{2}u^2 [\mu Q^2/6\pi a + 6\pi\mu^2 F^2 a^3/5].$$

When the quantities are expressed in ordinary units the result becomes

$$T = \frac{1}{2}u^2 [2\mu Q^2/3a + 3\mu^2 F^2 a^3/10].$$

If an electron be a conducting sphere of radius 10^{-13} cm. with a charge of 10^{-20} electromagnetic units, an electric force of a billion volts, or 10^{20} C.G.S. units, per centimetre, would not change its magnetic inertia by so much as one part in ten billions, and the results are of no consequence in experiments on the electrostatic deflection of cathode rays; but it is possible that there are other cases where it would be necessary to take the change of magnetic inertia into account.

When u becomes comparable with v , the analysis becomes more complicated, but does not present any difficulty, at least in the final stage, with finite conductivity, provided a Heaviside ellipsoid be substituted for a sphere.

In conclusion, I desire to acknowledge the help I have received from Dr. Heaviside's suggestions, and to thank Mr. Norman R. Campbell for verifying the formulæ.

G. F. C. SEARLE.

The Date of Easter.

THAT the formula of Gauss for finding the date of Easter fails in certain cases, of which the year 1954 is one, was pointed out by Gauss in his original paper in the *Monatliche Correspondenz* (vol. ii., p. 129), where he shows that there are the following two exceptions to the formula in the Gregorian calendar:—

(1) When the formula gives April 26, Easter falls on April 19.

(2) When the formula gives $d=28$, $e=6$, while $11M+11$ divided by 30 gives a remainder smaller than 19, then

Easter does not fall on April 25, as given by the formula, but on April 18.

These exceptions are caused by an inconsistency in the Gregorian rule, caused by the adherence to the old custom, that Easter should never fall later than April 25.

Armagh Observatory, June 22. J. L. E. DREYER.

THE discrepancy between the date of Easter, 1954, April 18 as given by the tables in the Book of Common Prayer, and April 25 as given by the formula of Gauss, arises from a purely artificial contrivance of Clavius, who arranged the reformed calendar, which is thus described on p. 55 of "The Prayer Book Interleaved," 1873, in an account of the calendar founded on a paper by Prof. De Morgan:—"It will never happen as to mean lunations, and rarely as to real ones, that in the same cycle there should be the lunation of a given month beginning on the same day in two different years of the cycle; and such a thing never happened in the unreformed Calendar. Clavius thought it desirable to imitate this in the new Calendar; and he observed that by taking the preceding day whenever the Epact was xxv., and the year of the cycle after the 11th, he could avoid the reiteration, and thus make the desired resemblance." "Whenever the Epact should be xxv., the year of the cycle being upwards of 11, say that the Epact is 26. This is not an astronomical correction, but a mere conventional mode of reconciling the choice which Clavius made of the mode of writing the Epacts with an essential peculiarity of the old cycle of 19 years which that mode of writing would have otherwise destroyed." "In 1954 the Golden Number is 17, the Sunday letter C, and the Epact according to the ordinary rule, xxv. Call it therefore xxvi. Thence April 17 will be the 14th day of the Paschal Moon, April 18, Easter Day. If the Epact xxv. were used April 25 would be Easter Day." The paper by Prof. De Morgan will be found in the "Companion to the British Almanac" for 1845.

My copy of NATURE for April 5 has long since gone to Bolivia, but probably your correspondents will find that Gauss did not take into account this artifice of Clavius. If in this century golden number 6 and Sunday letter C had coincided, Easter would have been set on April 25, because 6 comes in the cycle before 11 instead of after it as 17 does. An inspection of Table III. for finding Easter will show in the two half-lines for April 17 and 18 the arrangement made by Clavius.

Banwell Vicarage, June 22.

C. S. TAYLOR.

Musical Thunder.

EARLY this morning a storm broke in this neighbourhood accompanied by heavy thunder. During the storm I noticed that two of the peals began with a musical note of distinct and definite pitch. The "musical" portion of the peal lasted for about two seconds in each case, and the frequency of the note was both times about 400 per second.

This sound closely resembled a foot-fall in a narrow alley between high walls, and was only heard in two consecutive peals, separated by an interval of about a minute, the first being much more definitely musical than the second. In each case the interval between the flash and the first sound of thunder was about five seconds.

As is well known, a peal of thunder from lightning near at hand frequently sounds like a quick succession of raps or a volley of guns. Can the successive raps have followed one another so rapidly in this case that they combined to form a note?

If so, and if this note was due to a special configuration of reflecting surfaces in the clouds, possibly to others in slightly different positions, considerably different frequencies may have been observed.

The fact that two peals only sounded in this manner separated by the short interval of about one minute, and that the second was not so decidedly musical as the first, seems to indicate that they were due to some rapidly changing source such as one might expect the reflecting surfaces of a cloud to be. I listened carefully to deter-

mine that the note had its origin outside and was not due to resonance within the room, and in the second peal it was certainly outside, and probably had the first had its origin within the room I should have observed it.

I should be very glad, to hear if anyone has observed a similar phenomenon.

G. H. MARTYN.

1 Marden Road, S. Tottenham, N., June 24.

How do Inquiline Bees find the Nest of their Host?

THE following observation may serve to throw light on the above question, which has doubtless occurred to many entomologists. Yesterday I saw a specimen of the inquiline *Coelioxys quadridentata* enter the burrow of a leaf-cutter bee, *Megachile circumcincta*. I dug the nest out of the burrow, and in so doing scattered the sand over an area of several square inches, completely destroying all appearance of a burrow. I sat down to await the return of the *Megachile*, in order to identify the species, and was much astonished to see (and capture) in the course of the next ten minutes two more specimens of *Coelioxys*, which came hovering over the spot and alighted on the disturbed soil. I can think of no other explanation than that these "cuckoos" were attracted to the spot by the scent of the excavated nest. I may add that during several hours spent on the heath where this occurred I saw no other specimens of *Coelioxys*, and, further, that there was a fresh south-east breeze blowing at the time, and that the bees came up against the wind.

OSWALD H. LATTER.

Charterhouse, Godalming, June 24.

THE DISTURBANCE OF GREENWICH OBSERVATIONS.

IN the House of Lords on Thursday last, June 21, attention was directed to the threatened danger to the continued efficiency of the Royal Observatory, Greenwich, caused by the great electrical generating station erected by the London County Council about half a mile due north of the observatory. The danger was referred to by the Astronomer Royal in his report to the Board of Visitors on May 30, a summary of which appeared in NATURE of June 7 (p. 135). The generating station is situated exactly in the Greenwich meridian, as will be seen from the accompanying photograph of a view looking north over the top of the transit room; and the tall chimneys shown in the picture, as well as the heated air from them, will obviously interfere with some observations of northern stars, which are essential for latitude and refraction. Moreover, from tests already made it appears that the powerful engines which are being installed at the generating station will cause vibrations that will seriously affect the value of observations by reflection from a mercury horizon, required for the fundamental work of the observatory.

This is not the first time that the effects of generating stations and electric tramway systems in the neighbourhood of the observatory have been pointed out. About six years ago the question of the possible effect of disturbances from electric railways on the magnetic work carried on at the observatory was given careful consideration; and the hope was then expressed that in the event of future electric tramways regulations would be laid down by the Board of Trade to secure adequate protection for the magnetic work. The records in this department of the observatory have been obtained continuously on a general system for sixty-five years, but the astronomical work extends over more than two centuries and a quarter, and it would be unfortunate if circumstances should arise to break this chain of continuity.

The generating station established at Deptford - nearly a mile from the observatory—to supply the London County Council Tramways with electric